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ACTIVE FAULT MAPPING AND EVALUATION PROGRAM

TEN YEAR PROGRAM TO IMPLEMENT ALQUIST-PRIOLO SPECIAL STUDIES ZONES ACT

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THE CALIFORNIA DIVISION OF MINES AND GEOLOGY

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ACTIVE FAULT MAPPING AND EVALUATION PROGRAM

TEN YEAR PROGRAM TO IMPLEMENT ALQUIST-PRIOLO SPECIAL STUDIES ZONES ACT

BY THE

DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

A REPORT TO THE CALIFORNIA LEGISLATURE

DECEMBER 1, 1975

Pursuant to recommendations 7 and 8 of Budget Item 229 in "Analysis of the Budget Bill of the State of California for the fiscal year July 1, 1975 to June 30, 1976." Report of the Legislative Analyst to the Joint Legislative Budget Committee and adopted by the Committee on Conference of the California Legislature.

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PREFACE

This report is in response to the recommendation by the Legislative Analyst, and adopted by the Committee on Conference, that the Division of Mines and Geology report its plans for the active fault mapping program to the Legislature by December 1, 1975.

From Legislative Analyst's report "Analysis of the Budget Bill..." for fiscal 1975-76, section headed "Resources, Department of Conservation" page 398:

> **Fault Mapping Program Open-Ended**
>
> *We recommend approval of the division's request for $94,167 for the special study zones fault mapping program with the requirement that the division report to the Legislature by December 1, 1975 on its plan for the program, including funding levels, fault traces to be mapped, priorities and completion dates.*
>
> Chapter 1354, Statutes of 1972, requires the State Geologist to delineate and map special study zones to encompass as a minimum the traces of the San Andreas, Calaveras, Hayward and San Jacinto Faults and such other faults he may deem a hazard to structures. The purpose of the work is to provide data for cities and counties to establish zoning and building regulations for these geologically hazardous areas. The law provided that state and local costs be financed by a fee established by the State Mining and Geology Board and levied by local government against each applicant for a building permit within a special study zone. The board set a fee of $1 per $1,000 of construction cost, to go into effect July 1, 1974. One-half of this fee went to local government for administration costs, and the other half to the division.
>
> Chapter 1341, Statutes of 1974, gave local government the authority to set the fee and receive all revenue. Thus the General Fund must now support without reimbursement all state costs of the program. Work on the four faults mentioned above has now been completed, and the special study zones are now being extended to other areas. Like the strong-motion instrumentation program, this program lacks a plan defining its scope and priorities.

From Supplementary Report of the Committee on Conference Relating to the Budget Bill, Reflecting Agreed Language on Statements of Intent, Limitations, or Requested Studies, 1975-76 Fiscal Year, by Legislative Analyst, June 16, 1975, page 16:

> Item 229 - Department of Conservation
>
> *It is recommended that:*
>
> 3. *The Division of Mines and Geology report to the Legislature by December 1, 1975 on its plan for the fault mapping program, including funding levels, fault traces to be mapped, priorities and completion date.*

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ACTIVE FAULT MAPPING PROGRAM

(ALQUIST-PRIOLO SPECIAL STUDIES ZONE ACT)

SUMMARY STATEMENT

The Division of Mines and Geology active fault mapping program (Alquist-Priolo Special Studies Zone Act of 1972) was established in Chapter 7.5, Public Resources Code. The objective of the program is to provide for the public safety from surface rupture in hazardous fault zones, by restricting construction astride active fault breaks. Under the Act, the State Geologist delineates special studies zones about one quarter mile wide along potentially hazardous faults, starting with the State's four major faults: the San Andreas, Calaveras, Hayward, and San Jacinto faults. Under policies generated by the State Mining and Geology Board, local governments permit certain development projects in the special studies zones only after geologic study shows building sites to be free of hazardous faults.

During 1973, the first year of the program, 3 geologists and a geologic aid delineated special studies zones along the four major faults, on 175 7½-minute quadrangle maps; after public review, these maps were offically issued on July 1, 1974. During 1974-75, faults in an additional 81 quadrangles were zoned and reviewed, for official release January 1, 1976; 5 of the 1974 maps were revised for reissue too.

The 1974-75 fault-zoning program had a significantly different emphasis from the first year's, because it had to deal with faults about which comparatively little is known, geologically. The burden of making geological determinations whether particular faults are "sufficiently active" to constitute potential hazard fell on the Division -- this had been no problem for the four major faults, which were well known to have had recent and repeated movements. The 1974-75 production of zoned quadrangles was about half the 1973 rate, partly because the work team was reduced to three geologists, but mainly because the relatively unstudied faults being zoned required time-consuming checking and analysis to ascertain if they are sufficently active to warrant zoning.

Since July 1, 1974, about 200 geologic reports, statewide total, accompanied applications for permits to build a variety of structures in the designated special studies zones. The 79 local governments with lands affected by the designated zones had to develop ordinances and procedures for administering the Act, under policies by the State Mining and Geology Board, and with frequent assistance and advice from the Division of Mines and Geology.

The present program plan report reviews the Division's three years of administering the active fault mapping program. The plan shows that the remaining potentially active faults known in the State will be geologically evaluated, and -- where deemed active, or potentially hazardous -- zoned, over the ten-year period 1976-86. This work schedule is based on continuing the 1975-76 levels of funding ($94,167) and staffing; a three-geologist team mapping and evaluating the hazard of about 300 linear miles of known fault breaks each year, out of the State's total of about 3,000 miles of unzoned potentially active faults. About 25 new special studies zones maps are expected to be issued each year, plus about 10 revised maps that update those issued earlier. When the 10-year active fault analysis program is complete, a maintenance-level program ($45,468 per year) will continue, updating the estimated 500 zone maps as new data comes in, keeping the maps in print and distributing them, and responding to public inquiries.

The 10-year program will continue to incorporate new geologic data as received from all sources, including fault information produced in the 10-15 ongoing geologic hazards mapping projects by Division geologists. Current active-fault information developed in this program is also used in other Division products, such as the "Fault Map of California", scale 1:750,000, to be published early in 1976.

The first three years of the active-fault mapping program have revealed some uncertainties and problems. Technical difficulties included an uneven quality of existing geologic maps and reports, as to the types and recency of faulting, and as to individual faults other than the four major ones; also an unreliable state of the art for confirming the presence or absence of an active fault by site geologists. Other difficulties included the fact that most local governments lack staff geologists, and are unfamiliar with the concept or detail of geologic hazards; the relatively high cost and inefficiency of geologic reports that deal only with fault-rupture hazard; and economic impacts of zoning, felt by owners and developers of sites in the special study zones.

Nevertheless many of these startup difficulties have been solved, or at least accepted, and remedies are in sight for the rest. Unquestionably the program has increased public safety from the hazard of fault rupture. A longer range public policy benefit was also accomplished: the establishment of a working mechanism for dealing with all sorts of critical land-use hazards -- the special studies zone concept. Now, the program needs to shift emphasis from simply zoning well known active faults, to evaluating the State's numerous other potentially hazardous faults. To fulfill the Legislature's intent to provide for public safety, it is important to complete the proposed ten-year program at the modest level planned.

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ACTIVE FAULT MAPPING AND EVALUATION PROGRAM

INTRODUCTION

This report is in response to the Legislative Analyst's and Legislature's requests (Preface) for the Division of Mines and Geology's plan defining the scope and priorities of its program of active fault mapping (established by Alquist-Priolo Special Studies Zones Act of 1972; Appendix A). This report is the requested plan, including objectives, policies, funding levels, fault traces to be mapped, priorities, and completion dates.

This report also presents important background data on what geologists know -- and don't know -- about faults; about the Alquist-Priolo Act; and some of the problems and experiences met in three years' experience administering it.

CONCLUSIONS AND RECOMMENDATIONS

The principal conclusion is that despite some technical problems with the startup phases of the Alquist-Priolo active fault zoning program, it is a valuable State program. Following the plan in this report, the program will be completed in 10 years, and then continued at a maintenance level. The people of California are well served in the area of seismic hazards safety by the present program of identifying and mapping the active faults in California, and evaluating their potential hazard. To consider diminishing the program after only three years' experience -- whether for reasons of economy, or based on the wish that broader, better geologic hazard legislation might be forthcoming some day -- would be to abdicate the State's basic responsibility to provide for geologic and seismic safety in California.

The planned active fault mapping and evaluation program will evaluate about 3,000 miles of potentially active fault breaks, during the ten years 1976-86, requiring funding of $94,167 each year. In 1986-87, the evaluation and zoning will be complete, but maintenance and updating activities will continue, at a cost of $45,468 each year.

Legislative approval of the plan presented here, through the budget-approval process, will be a positive step in continuing to improve at least the fault-rupture aspect of seismic safety in California. If legislation can be passed extending the benefits of adequate geologic and seismic reports evaluation to help identify and avoid or mitigate all the geologic hazards present before construction developments are permitted in geologically hazardous areas, then the Alquist-Priolo active faults program can be assimilated into that comprehensive program. Until then, the active fault mapping program should be vigorously pursued by the Division of Mines and Geology, according to the plan herein.

In brief, the plan presented herein to continue the Division of Mines and Geology's special studies zones active fault mapping program embodies these main points:

1. Ten work areas scheduled, with indicated priorities and equal division of 3,000 miles of potentially active faults into 10 one-year work segments.

2. Priorities for completing annual work areas are based on population, and distribution of suspected active faults.

3. Flexibility is planned in completing scheduled work areas, to allow for immediate preparation of revisions or new maps whenever significant new fault data are received.

4. Annual cycle to be 21 months:
    Evaluation: 12 months (year of work-area priority)
    Zone and issue about 25 preliminary maps, plus 10 revised: 3 months
    Review, and comments returned: 3 months
    Revise, and issue official maps: 3 months (October 1, following year)

5. Budget is $94,167 per year; projected costs $110,304. ($16,137 difference to be made up by redirecting staff time, reducing map publication costs, and sharing costs with interface programs.)

6. Maintenance phase, starting 1986, @ $45,468 per year, to continue updating official maps, keep materials in print and distribute, maintain open file of geologic reports, advise and inform public agencies and individuals about procedures under the Act.

FAULT RUPTURE HAZARD IN CALIFORNIA

California is laced with faults -- fracture planes in the earth's crust along which the rocks or soil on opposite sides of the break have moved. When the movement is sudden, the shock is called an earthquake; when the movement is slow and gradual, it is called "fault creep". Structures built directly astride the surface traces of active faults are subject to various degrees of damage, depending on whether -- and how much -- the fault moves again.

Figure 1 shows the principal known faults in California, classified in two groups according to how recently they have been active. The more recently active group (colored red) includes all faults believed to have been active during Quaternary time (last 2 million years, including Holocene time: last 11,000 years; and Historic time: last 200 years). In terms of future activity, all the red faults are "potentially active." Only those that can be shown to have been active at least once during Holocene time will be classed "active," and zoned. Those that can be determined to have remained inactive throughout Holocene time will not be zoned.

The other group (colored black) includes two subgroups: 1. those faults that have not moved during Quaternary time, so are classed inactive, and 2. those faults for which no dates of movement are determinable -- and these may include some Holocene faults, which will be classed active and zoned if and when they are so evaluated.

All the potentially active (red) faults are scheduled for evaluation and possible zoning during the 10-year Active Fault Mapping and Evaluation program planned herein, so that those with Holocene movement can be identified and given Special Studies Zones.

Difficulties Identifying and Evaluating Faults

In order to identify faults as active, and to evaluate the degree of their hazard potential, a geologist must be able to:

1. Locate its trace accurately on the earth's surface; and

2. Determine how active it is, based mainly on how recently it last moved. The frequency and amount of past movements and associated seismicity are other factors that help geologists evaluate a fault's relative hazard potential.

Geologists are aware of hundreds of faults in California, but when it comes to details, they have much to learn about the recognition and evaluation of individual faults. Earth stresses have persisted from the earliest geologic times in most parts of California, resulting in the formation of fault breaks in formations of nearly every age, including the youngest known. The faults that juxtapose different types of rock at the surface, or that leave sheared, ground-up "gouge" zones from repeated movement, are relatively easy for geologist to recognize and locate accurately. However, such faults may be difficult to evaluate as to recency of activity if, as is common, they displace only very old rocks. Those few faults that have moved during historic time -- especially those that moved during earthquakes -- are also relatively well known, and easily classed as active. Unfortunately, the many known faults that reach the surface in areas of alluvium or thick soil mantle tend to be relatively hard to recognize or to locate accurately, because discernable difference in soils type may not appear on the two sides of the fault, and because any other topographic features that may have been caused by the fault are soon lost to weathering or cultivation. Even after digging expensive trenches or bore-holes, geologists still may be uncertain of the exact position of many faults -- even some of the relatively important ones.

Even after a fault has been recognized, and its surface trace located accurately, the uncertainties of estimating whether its future movements will indeed be hazardous are exceedingly great. Such movement-detection methods as repeating precise surveys across a given fault at yearly intervals to detect possible miniscule slip, or setting arrays of seismographs to detect microseisms caused by incipient deformation or slippage at depth, are too expensive and too time consuming to be feasible in protecting modestly priced structures and engineering works. The main practical means available to geologists for judging whether or not a fault will become active in the future is based on recency of fault movement. Omitting a recital of rationale, the assumption of geologic science, upon which Alquist-Priolo fault zoning and site evaluations are based, is that the likelihood of future movement of the crust along any fault is directly related to its most recent past movement. Other factors of potential fault behaviour that may be deducible from observed past fault movement include:

1. Magnitude of possible future break: how big was its most recent break, and how much was the total cumulative offset -- in feet of offset, or length of traceable surface rupture?

2. Direction of possible future movement: was the most recent offset vertical or lateral? What is the orientation of the fault?

3. Timing of possible future break: its next break is most likely to occur within a future time span equal to that which has passed since its most recent break.

4. Location of possible future break: its next break is most likely to recur along the same trace as its most recent break.

Two basic fallacies challenge the placing of too much confidence in the above principles:

1. These details of past movements on particular faults are not always measureable, or even detectable; the dating of "most recent movement" depends on being able to age-date the youngest formation the fault displaces or on recognizing recent fault-related geomorphic features and the oldest one it does not displace -- lines of evidence commonly obscured with unknowns, and

2. Abundant observations confirm that recurrent movements along faults are not always confined to exact locations, magnitudes, directions, or time scales of previous movements. The generally accepted geologic concept that the earth strains that cause faults tend to migrate in location and direction over extended geological time further weakens the idea that the future behaviour of a fault will precisely mirror its past behaviour.

The limitations of geologic art in fault study apply not only to the State Geologist and his staff in delineating the special studies zones, but also to the geologist at a construction site within a special studies zone, seeking to prove the presence or absence of hazardous faults where the proposed foundations are to go. The site geologist's problem commonly is to decide whether no fault exists, or whether a fault really does exist, even though it is not visible -- either not breaking through those topmost layers that he can examine with a trench, or breaking those layers but still being undetectable even in a trench, boring, or other means.

Surface rupturing of previously undetected faults or branches of well known faults, and of faults previously considered inactive, occurred during the earthquakes near Oroville (1975), San Fernando (1971), and Tehachapi (1952), clearly demonstrating that despite previous geologic study of those areas, the potential threat of some rather dangerous faults still had not been detected and evaluated. The conclusion is inescapable that other active faults in California will also surprise us by breaking in unexpected places in the future. Until geologists have located a fault, and evaluated its potential threat through a program like the active fault mapping program, there is no way the public can be warned not to build structures on top of it. Even so, all active faults cannot be identified at this time.

Another limitation to an ideal program of guaranteeing public safety from fault damage is that most faults are really complex zones of faulting, where the repeatedly strained earth's crust has broken in multiple fault planes. For example, the San Andreas fault, which has been repeatedly active over extensive geologic time, consists of thousands of seim-parallel fault breaks, shattering a zone now a mile or more wide in places. Is any particular fault break in this zone more likely than any other to be active in the future? Which one -- how can we recognize it? Why should the most recent of the thousands of past breaks in any stretch along the zone be the one most likely to break next time? Geological history tells us to beware of simple answers to these questions. Prudence dictates that we not build significant structures anywhere in such zones -- or that we build only those that we can afford to expose to fault damage.

Most major faults have branching and secondary faults angling outside the main fault zone; these also may be "active," hence, hazardous during fault rupture. The identification and evaluation of branching and secondary faults are generally even less certain than they are for the main fault breaks, because lesser fault displacements leave less obvious fault evidence.

All these factors pose serious limitations to any geologist's abilities to identify all the potentially active faults in California, especially to pinpoint with any strong degree of certainty those most capable of future movement.

Nonetheless, despite the uncertainties of quantitatively predicting the future degree of hazard of particular faults from their past behaviour, these concepts indicate the present state of the art of fault evaluation: they are the best methods available, so it is correct to apply them in a probablistic sense to estimate the likelihood of future fault hazard in the Division's active fault mapping and evaluation program.

The practical difficulties indicate that not all hazardous faults will ever be identified in advance of being built on -- by the State Geologist, or by site geologists. Nonetheless, many of California's most hazardous faults have been and can be recognized, evaluated, and zoned before development is permitted. Building on those faults can be avoided, thereby significantly reducing the risk of losses from surface fault rupture. This tangible benefit, which has an attainable benefit: cost ratio of about 2:1 ("Urban Geology Master Plan for California", Division of MInes and Geology Bulletin 198, 1973, page 100), is the goal of the Alquist-Priolo special studies zones program.

LEGISLATIVE ACTION: THE ALQUIST-PRIOLO ACT

In 1972 the Legislature passed the Alquist-Priolo Special Studies Zones Act, partly as a result of studies of California's seismic safety problems by the Legislature's Joint Committee on Seismic Safety and the Governor's Earthquake Council. Experience of losses in the San Fernando earthquake of February 9, 1971, added impetus. The Act (see Appendix A) provided a mechanism to reduce losses from surface fault rupture, on a statewide basis. The intent of the Act, "to provide for the public safety in hazardous fault zones," is stated in Section 2621.5 of the Public Resources Code. The Act is notable as the first concrete step towards requiring the application of geologic reports statewide to reduce losses from a specific seismic hazard.

Requirements of the Act

The Act requires concerted efforts by the State Geologist, by the State Mining and Geology Board, and by local government; it also requires the seller of any property in a special studies zone to disclose that fact to any prospective buyer. The Act also has major impact on the owner or would-be developer of zoned lands to obtain the required geologic reports, and possibly to cope with problems of faults that cut through their lands.

1. State Geologist

   The Act requires the State Geologist to delineate "special studies zones" about a quarter of a mile wide along four of California's principal hazardous faults -- the San Andreas, Calaveras, Hayward, and San Jacinto. Also the Act requires the State Geologist to zone such other faults as he deems "sufficiently active and well-defined as to constitute a potential hazard to structures", and permits him to approve waivers of geologic reports, where it is shown that no undue hazard exists.

2. State Mining and Geology Board

   The Act requires the State Mining and Geology Board to adopt policies and criteria (Appendix B) to assist local and state government agencies in providing for public safety. The Board also acts as an appeals board.

3. Local Government

   The Act requires cities and counties to require geologic reports delineating any local hazard of surface fault rupture before they approve certain development projects in the special studies zones. Local governments are required to act in accordance with the Board's policies and criteria, and the State Geologist's findings.

The main responsibilities required by the Act are summarized in Table 1.

TABLE 1

FUNCTIONS AND RESPONSIBILITIES REQUIRED BY THE ALQUIST-PRIOLO SPECIAL STUDIES ZONES ACT OF 1972

STATE LEGISLATURE

- Established intent of Act
- Established concept of Special Studies Zones
- Established priority for first four faults to be zoned
- Established responsibilities for administering Act
- Provided funds to State Geologist for first year; fees to local governments

STATE GEOLOGIST

- Must establish Special Studies Zones (SSZ's)
  - Establish priorities, which faults to zone after first four
  - Identify potentially hazardous faults
  - Delineate special studies zones
  - Issue preliminary maps, for review
  - Issue Official Maps
- Must revise established zones as needed
- Must approve (or deny) waivers initiated by local government
- Must maintain public file of geologic site reports 1/
- Must provide general information and advice (e.g. on Act, Policies and Criteria, local government procedures, etc.) 2/

STATE MINING AND GEOLOGY BOARD

- Must establish Policies and Criteria to guide all concerned with administering Act
- Must serve as appeals board
- Must provide policy guidance to State Geologist, including advice on SSZ map review comments 2/

LOCAL GOVERNMENT: CITIES AND COUNTIES

- May review and provide comment to State Geologist on preliminary SSZ maps
- Must establish procedures and adopt ordinances to administer SSZ process locally
- Must require special studies to produce geologic site reports
- May initiate waivers for State Geologist's approval
- Must regulate specific development projects in SSZ
  - Provide technical review of geologic site reports: accept or reject
  - Grant permits if no undue hazard exists
  - Enforce permit conditions during construction 2/
- Must file geologic site reports with State Geologist 1/

TABLE 1 page 2

PROJECT (SITE) GEOLOGIST, RETAINED BY OWNER/DEVELOPER

Must conduct geologic site studies, provide reports
- Meet provision of Policies and Criteria
- Meet standards, regulations of local government 2/

SELLERS OF REAL PROPERTY IN SPECIAL STUDIES ZONES

Must disclose to prospective buyer that property is in SSZ

STATE AGENCIES

Must provide for public safety from the hazards of surface faulting
May review Preliminary Review Maps and comment to Board.

1/ Required by Policies and Criteria (Appendix B)

2/ General responsibility under pre-existing State or local codes

RESPONSIBILITIES OF THE STATE GEOLOGIST UNDER THE ACT

To be effective, the Act (Exhibit A) must be administered responsibly and vigorously by all who have functions or responsibilities under it, as outlined in Table 1. This section of this report presents mainly the role and functions of the State Geologist and the Division of Mines and Geology, with minor comment on interface activities with other responsible agencies.

Basic Responsibilities

The principal responsibility of the State Geologist under the Act is to establish Special Studies Zones: "Delineate special studies zones (ordinarily one-quarter mile or less in width) to encompass all potentially and recently active traces of the San Andreas, Calaveras, Hayward, and San Jacinto Faults, and such other faults or segments thereof, as he deems sufficiently active and well-defined as to constitute a potential hazard to structures from surface faulting or fault creep." Also, "... continuously review new geologic and seismic data and ... revise the special studies zones or delineate additional ... zones when warranted by new information."

Other provisions of the Act require the State Geologist:

1. to issue offical maps delineating the special studies zones (Figure 2) to concerned state agencies, and to cities and counties affected by the zones,
2. to provide for review and revision of preliminary zone maps, and
3. to grant waivers of geologic reports when justified.

Under the Policies and Criteria established by the State Mining and Geology Board (Appendix B), the State Geologist must also maintain an open file of the geologic reports required for those projects in the zone that are required to be permitted under the Act.

Implicit in performing these mandated responsibilities are the needs to:

1. Establish a work plan to complete active fault mapping program (this report contains that work plan for the years 1976-86).
2. Establish operational procedures, criteria, and priorities, and follow them in investigating, evaluating, and (if warranted) zoning faults in the work-plan areas.

Defining "Sufficiently Active and Well-Defined"

The Alquist-Priolo Act gave specific criteria for the State Geologist to apply in deciding which faults need special studies zones; he must deem them "sufficiently active and well-defined as to constitute a potential hazard to structures ..." (Section 2722). The State Mining and Geology Board Policies and Criteria regard "those faults which have had surface displacement within Holocene time (about the last 11,000 years) as active and hence constituting a potential hazard" (Review of Preliminary Maps, policy 3).

The given criteria alone were sufficient to guide the zoning of the designated four major faults and their branches, but to deal with the many less well documented active faults, the State Geologist needed to refine these criteria, as follows:

1. Sufficiently well defined: a fault is considered "sufficiently well defined" if its trace is clearly detectable by a trained geologist as a physical feature on the ground surface. Various state-of-the-art methods -- including observations of geologic or geomorphic features, and geophysical or seismologic indicators -- may be used (Appendix C). Reasonable extrapolations or interpolations may be applied along or between detectable surface traces, between isolated evidence of discontinuous breaks, or along branches or segments of detectable faults. Professional judgment is required, applying these fault-location criteria.

2. Sufficiently active: a fault is deemed to be "sufficiently active," and therefore potentially hazardous, if the most recent movement along one or more of its segments or branches can be dated, by evidence or inference, within Holocene time (last 11,000 years).

   Evidence of a fault's activity in Historic time (last 200 years) may include one or more of the following:

   a. Observed historic fault rupture or creep

   b. Evidence of seismicity clearly associated with the fault (e.g. rupture during earthquake, seismograph records)

   c. Strain measurable across the fault (e.g. creep meters)

Professional judgment is required applying all these types of fault-activity criteria.

The principal uncertainties in dating a fault's most recent movement accurately are 1. very recent soil or alluvium may mask even significant Holocene movement; and 2. geologically recent rocks may simply not be present along the traces of most California faults. For practical purposes the State Geologist has adopted the criterion that faults that lack the direct evidence of displaced Holocene rocks, but have their latest movement datable as Quaternary (within the last 2,000,000 years) are "potentially active." If other criteria of relatively recent movement are present, such as inferential geomorphic evidence or indicated Holocene movement on branch faults, such faults are deemed to be "sufficiently active", and to warrant special studies zones.

Criteria of recurrent movement, significant offset, and significant seismicity are all judgmental; indicators commonly are difficult to detect, and even harder to evaluate.

Examples of faults that require special judgment as to whether they should be zoned or not include those, like the Newport-Inglewood fault zone, which have evidence of being active at depth, at least in places, but which lack well defined traces at the surface. Another type of fault with zoning questions includes the swarms of normal faults in Quaternary volcanic rocks (e.g. Modoc County, and near Bishop, in Inyo and Mono Counties). They are definitely located, and unquestionably cut Quaternary rocks; still, many of them lack clear evidence of recurrent movement, their offset commonly is insignificant, and no information is available on their seismicity. Furthermore, most of these faults apparently resulted from local crustal adjustment at the time of volcanism, rather than from the more persistent and wider-spread types of tectonic crustal stresses that would be expected to cause recurrent movements. Some such faults may be recently active -- but still may not be sufficiently active to warrant zoning: reliable criteria need to be developed.

Method of Delineating Special Studies Zones

Once a fault is determined to be active, hence potentially hazardous, its surface trace is drafted on a standard U.S. Geological Survey 7½-minute topographic map, scale 1:24,000 (one inch equeals 2,000 feet). All available data are used, and conflicting ideas of different geologists are resolved, to plot the fault trace as accurately as possible. Nearby and subsidiary fault traces are evaluated to determine if they, too, should be included in the zone or not.

The special studies zone is then established by selecting turning points representing, if possible, visible ground features about one-eighth mile on either side of the fault trace. The zone boundaries are drafted as straight lines connecting the turning points. Straight-line segment ends are drafted for zones at least one-eighth mile past the plotted position of each fault. For faults that extend from one map to another, identical turning points are placed at the common boundary, on both maps, wherever feasible.

Swarms of en echelon fault traces, branching segments, curved or discontinuous traces, and wide crushed zones along some major faults are special problems and may cause irregular zones. Faults with multiple, or separated branches, that have Holocene movement on some segments but not on others, or that have widely separated, discontinuous bits of evidence also pose problems as to how wide or far to extend the zones in those localities. A working policy for zoning branching active faults is to include in the zone only the branch faults for which there is evidence of Quaternary (about 2 million years) movement.

Fault-Zoning Program, 1973 through 1975

In January 1973 the State Geologist assigned three geologists, a geologic aid, a geological draftsman, and a clerk-typist to produce and distribute the Special Studies Zones maps. As required by the Act, maps delineating special studies zones along the San Andreas, Calaveras, Hayward, and San Jacinto faults were completed in preliminary form by December 31, 1973. Faults shown on these initial maps were based almost entirely on available geologic maps of other geologists and entailed no field work on the part of the project staff.

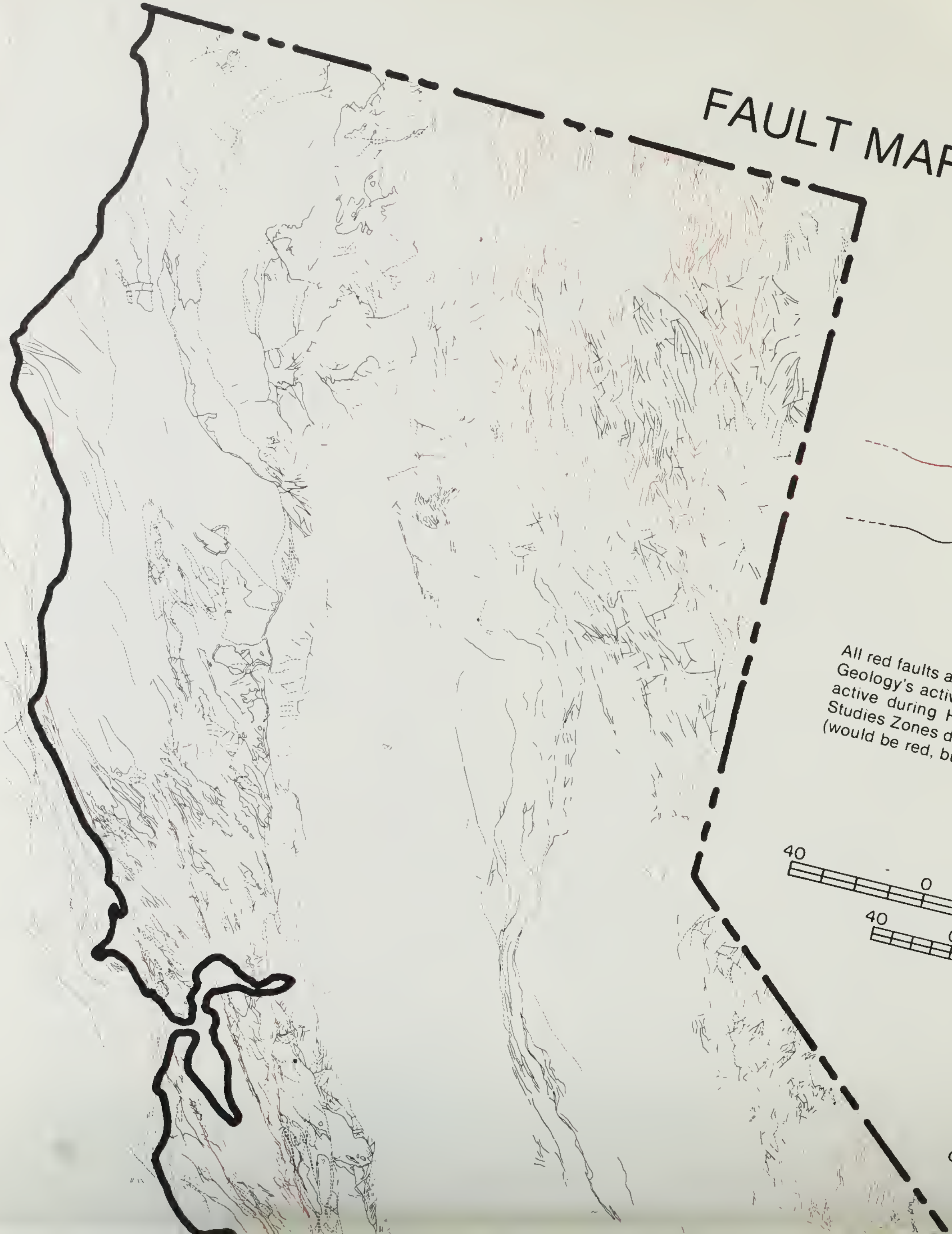
The preliminary maps were distributed to all counties and cities with lands in any special studies zone, and to other public agencies for review and comment within 90 days. Many of the local governments held public meetings to explain the maps and procedures, and to get public comment. After incorporating comments generated by these reviews, the State Geologist issued the first set of 175 Official Maps on July 1, 1974 (Figure 2 is example). The process took 18 months -- a year to compile preliminary maps, and six months for review, correction, and final release.

The second batch process started July 1974, with the project staff reduced by one geologist. The faults selected for the 1974-75 phase of the project included all other known historically active faults in California, and a few other faults considered to have a relatively high potential for future surface rupture. The faults selected for zoning in 1974-75 were:

Antioch
Buena Vista
Fort Sage
Garlock
Kern Front
Manix
Newport-Inglewood
Owens Valley
Rogers Creek/Healdsburg
San Fernando
San Gregorio
White Wolf

Eighty-one new zone maps were issued in preliminary form for review on July 1, 1975, to be issued as Official Maps on January 1, 1976. In addition, five zones maps of the 1973-74 batch were revised where new data on a segment of the San Andreas fault indicated a need for revision. Copies of the revised maps also were issued in preliminary form on July 1, 1975, for 90-day review and revision periods, prior to becoming official on January 1, 1976.

FAULT MAP OF CALIFORNIA



FAULT CLASSIFICATION

Faults with historic (last 200 years) or Quaternary (last 2 million years) displacement.

Faults with pre-Quaternary (older than 2 million years) or unrecognized Quaternary displacement.

NOTE

All red faults are potentially active and will be evaluated in the Division of Mines and Geology's active fault mapping and evaluation program. Those found to have been active during Holocene time (last 11,000 years, approximately) will have Special Studies Zones delineated. Some black faults and some concealed Quaternary faults (would be red, but not shown) may also be found to be active, and zoned.

SCALE

SOURCE

Fault information from Division of Mines and Geology "Fault Map of California", scale
compiled by Charles W. Jennings

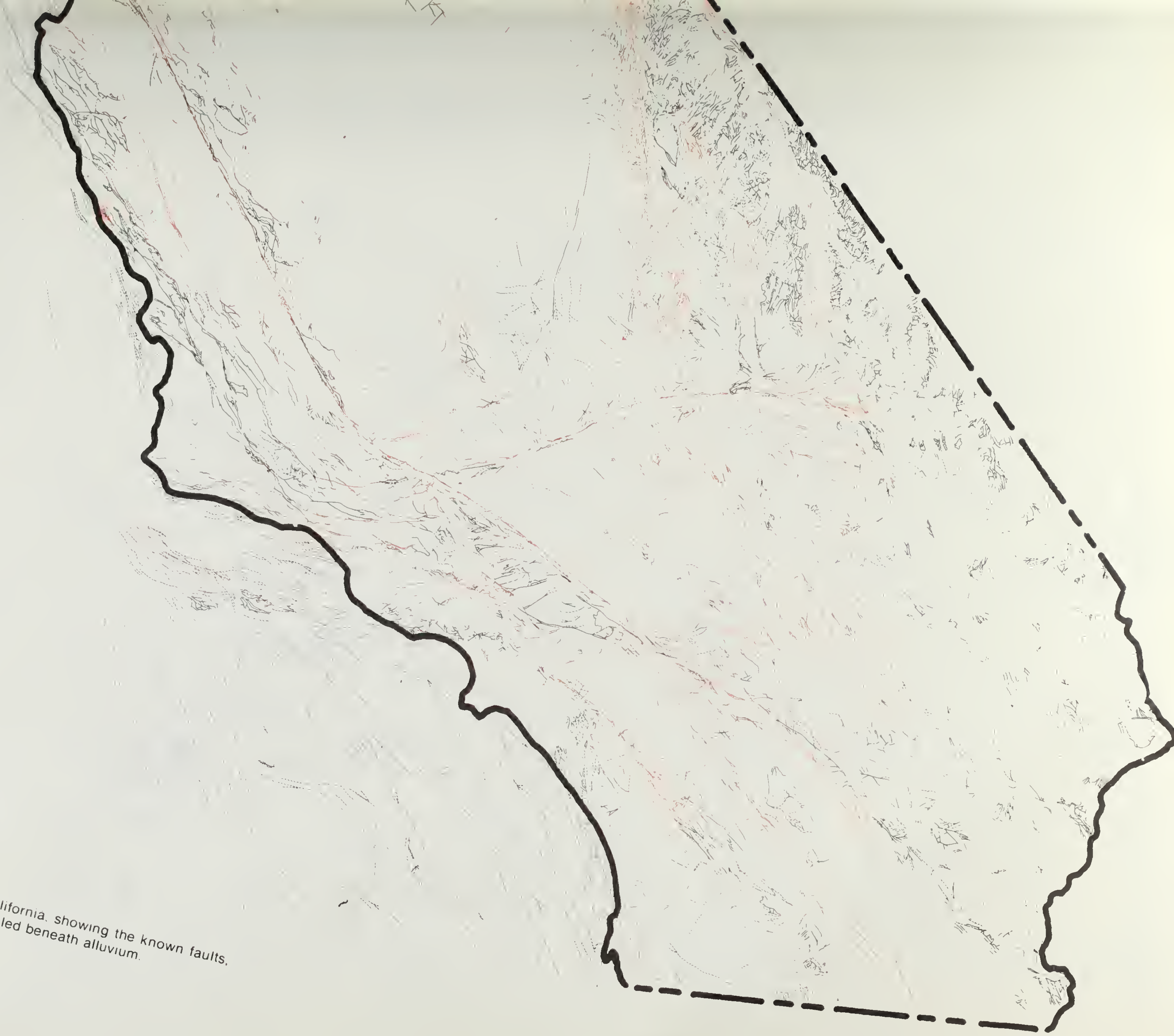
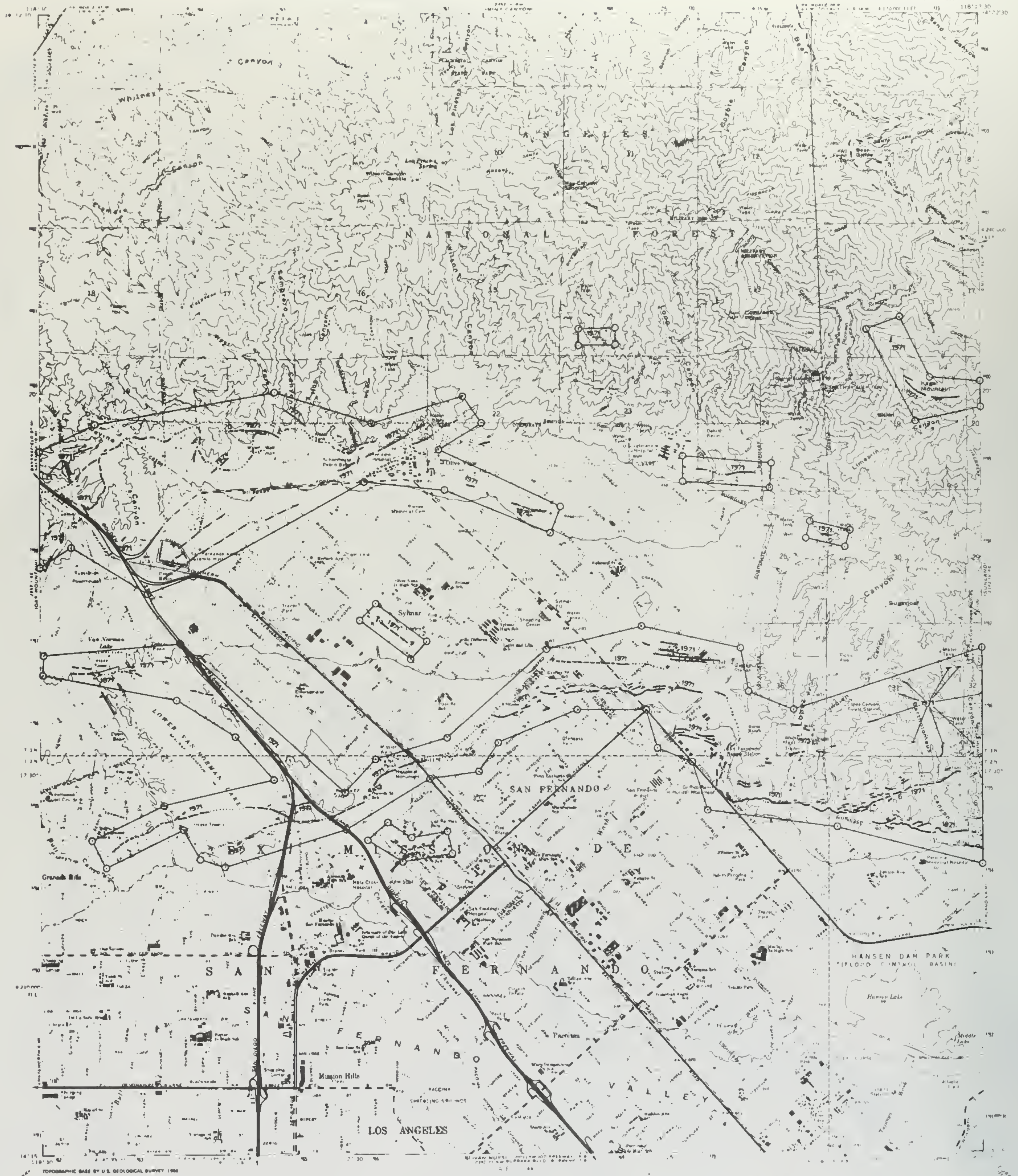


Figure 1. Outline of California, showing the known faults, excluding those concealed beneath alluvium.

CALIFORNIA DIVISION OF MINES AND GEOLOGY
THOMAS E. GAY, JR. ACTING STATE GEOLOGIST

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF CONSERVATION

SAN FERNANDO QUADRANGLE
CALIFORNIA – LOS ANGELES CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



MAP EXPLANATION

Potentially Active Faults

Faults considered to have been active during Quaternary time, solid line where accurately located, long dash where approximately located, short dash where inferred, dotted where concealed; query (?) indicates additional uncertainty. Evidence of historic offset indicated by year of earthquake-associated event or C for displacement caused by creep or possible creep.

Aerial photo lineaments (not field checked); based on youthful geomorphic and other features believed to be the results of Quaternary faulting

Special Studies Zone Boundaries

These are delineated as straight-line segments that connect encircled turning points so as to define special studies zone segments.

Seaward projection of zone boundary

STATE OF CALIFORNIA
SPECIAL STUDIES ZONES

Delineated in compliance with Chapter 7.5, Division 2 of the California Public Resources Code

SAN FERNANDO QUADRANGLE

OFFICIAL MAP

Effective: January 1, 1976

T. E. Gay Jr. Acting State Geologist

REFERENCES USED TO COMPILE FAULT DATA

San Fernando Quadrangle

Barrows, A. G., Kahle, J. E., Saul, R. B., and Weber, F. H., Jr., 1975, Geologic map of the San Fernando earthquake area in San Fernando, California, earthquake of 9 February 1971: California Division of Mines and Geology Bulletin 196, pl. 2.

Barrows, A. G., Kahle, J. E., Weber, F. H., Jr., Saul, R. B., and Morton, D. M., 1975, Surface effects map of the San Fernando earthquake area in San Fernando, California, earthquake of 9 February 1971: California Division of Mines and Geology Bulletin 196, pl. 3.

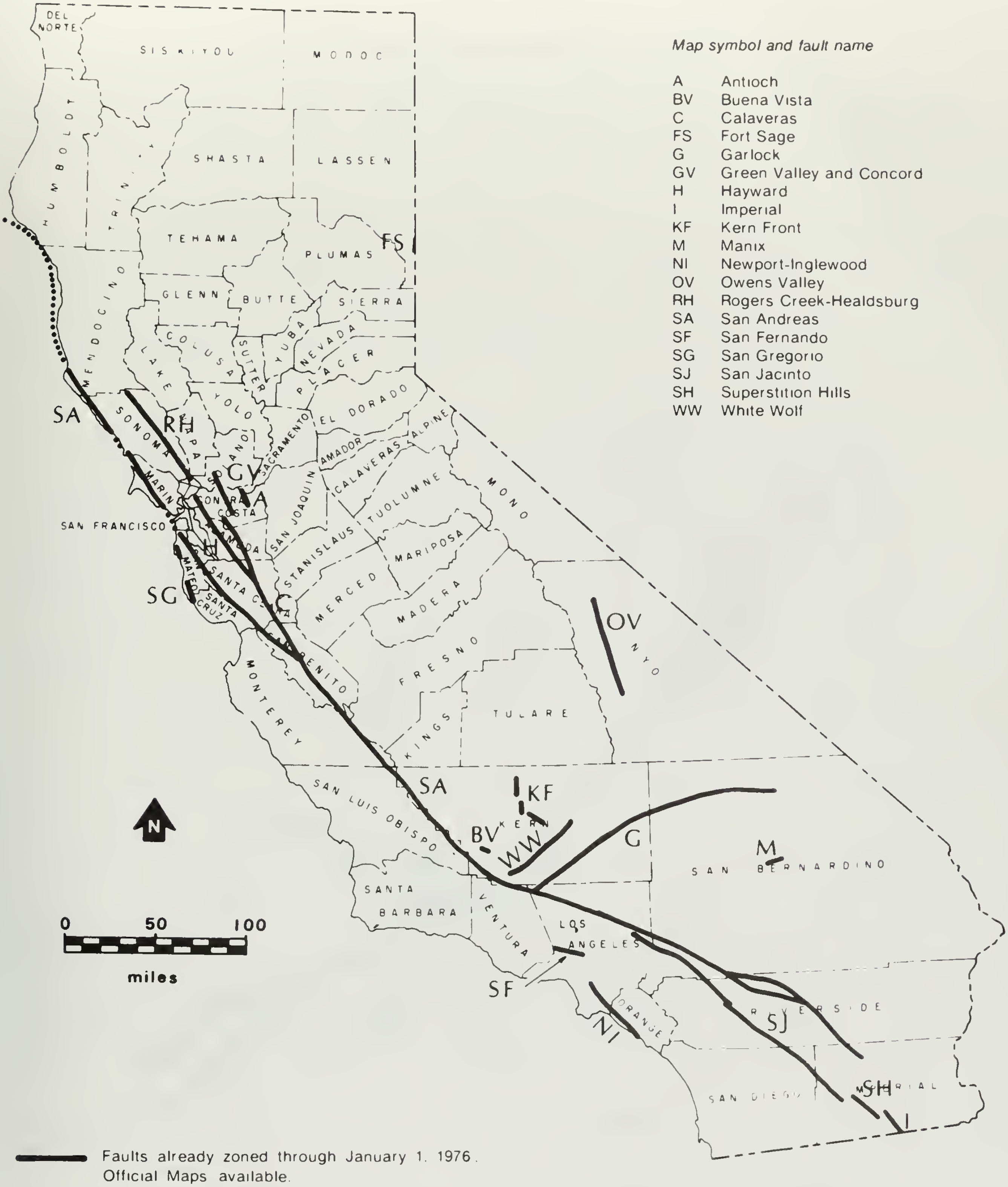
Yerkes, R. G., Bonilla, M. G., Sims, J. D., Wallace, J. B., and Frizzell, V. A., Jr., 1973, Maps showing faults and ruptures of the Van Norman Reservoirs area, northern San Fernando Valley, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-549.

IMPORTANT - PLEASE NOTE

1) *This map may not show all potentially active faults, either within the special studies zones or outside their boundaries.*
2) Faults shown are the basis for establishing the boundaries of the special studies zones.
3) The identification of these potentially active faults and the location of such fault traces are based on the best available data. Traces have been drawn as accurately as possible at this map scale, however, the quality of data used is highly varied. The faults shown have not been field checked during this map compilation.
4) Fault information on this map is not sufficient to serve as a substitute for information developed by the special studies that may be required under Chapter 7.5, Division 2, Section 2623 of the California Public Resources Code.

Figure 2. San Fernando Quadrangle, an example of an Official Special Studies Zones Map. (Originally issued at about twice this scale.)

ACTIVE FAULTS ZONED AS OF JANUARY 1, 1976



Map symbol and fault name

A	Antioch
BV	Buena Vista
C	Calaveras
FS	Fort Sage
G	Garlock
GV	Green Valley and Concord
H	Hayward
I	Imperial
KF	Kern Front
M	Manix
NI	Newport-Inglewood
OV	Owens Valley
RH	Rogers Creek-Healdsburg
SA	San Andreas
SF	San Fernando
SG	San Gregorio
SJ	San Jacinto
SH	Superstition Hills
WW	White Wolf

Faults already zoned through January 1, 1976. Official Maps available.

NOTE Other potentially active faults may be zoned in the future, and some of the existing zones may be revised when warranted by new fault data

Figure 3. Map of California showing faults that have been evaluated as active and for which special studies zones have been delineated and Official Maps issued, as of January 1, 1976.

SPECIAL STUDIES ZONES MAPS ISSUED

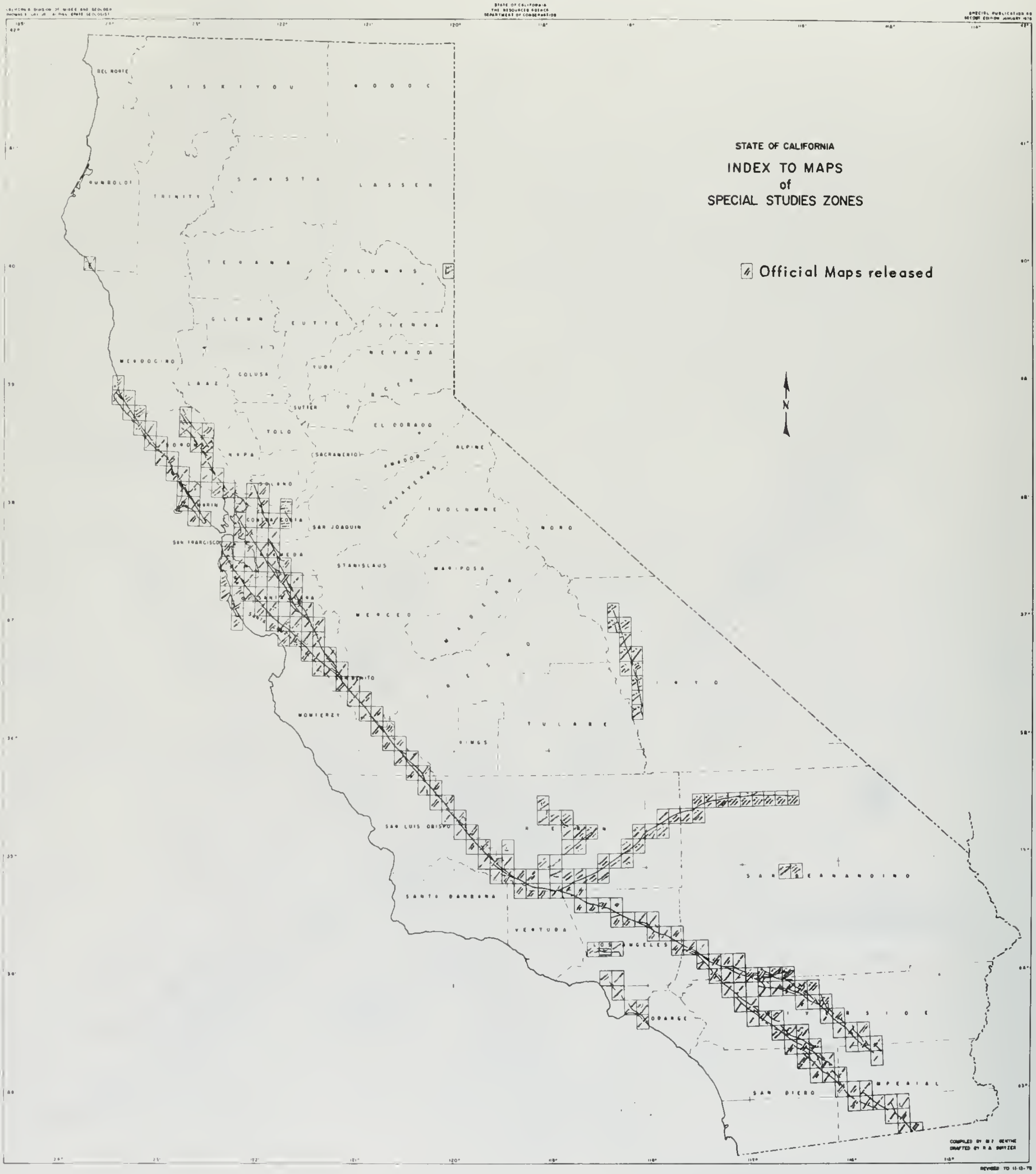


Figure 4. Map of California showing the 7½-minute quadrangles for which Official Maps are issued and in force, as of January 1, 1976. The total of 256 SSZ maps includes 175 issued July 1, 1974, and 81 issued January 1, 1976; five of the July 1, 1974, maps were replaced by revised versions dated January 1, 1976. *From California Division of Mines and Geology Special Publication 42, January 1976.*

The faults and zones delineated on this second group of 86 maps, as with the first group, were based almost solely on previous geologic work and interpretations, done by other geologists for purposes other than the special studies zone project. Figure 4 shows the 256 Official Special Studies Zones maps issued as of January 1, 1976, including 5 revised maps.

Two problems became apparent during the 1974-75 phase of the project. First, the geologic literature was notably lacking in reliable information on the host of lesser known active and potentially active faults in the State--relatively few had been studied or described as to their most recent activity, recurrence, potential for further movement, etc. Second, a rational priority system was needed to organize the hundreds of potentially active faults remaining to be considered for zoning into workable priority grouping.

During the 1974-75 project it was apparent that the zoning of most of these lesser known faults was going to be unsatisfactory if not impossible unless better information could be obtained. A common problem, for example, was deciding whether or not to zone the various branch and subsidiary faults seen within a few miles of each principal fault: which are actively associated, and which incidental? Which are most likely to be "potentially active"? It became clear that field studies by Division geologists would be the only feasible way to answer these questions.

Other activities carried out by the State Geologist and Division staff in response to the Act over the first three years, included:

1. Providing information and guidance to local jurisdictions, geologists, and others

2. Open filing geologic reports required under the Act

3. Acting on waiver requests

4. Providing staff assistance to the State Mining and Geology Board.

These activities are partly mandated by the law, and partly imposed indirectly -- but all were time consuming, and all were essential to the success of the special studies zone program, and implementation of the Act. Especially important was the providing of information and guidance to local government officials, consulting geologists, land owners, and land developers during the early months of the program, when very little was known of the intent, procedures, and pitfalls in the program.

Transition from Fault-Compiling to Fault-Study Program

It became apparent, starting 1974-75, that the emphasis of the Division's program had to change from compiling previous knowledge, to performing field work and fault-activity analysis to refine and augment pre-existing information.

The intent of the Act to provide for public safety makes it clear that the State Geologist is obligated to consider also the many other less well known faults in the State, to determine which of them warrant special studies zones. Despite the fact that many other comparatively recent faults are known or suspected to be potentially hazardous, the Division staff found existing data to be inadequate for identifying those that should be zoned. The hundreds of Quaternary faults shown in red on Figure 1 are by definition potentially active, and some of them no doubt have a high potential for surface rupture, whereas many do not. Still others are not sufficiently well-defined, and are not amenable to site-geologic evaluation, so zoning will remain impractical.

The Division's 10-year program plan from 1976 to 1985 is basically focused on conducting the geologic investigations necessary to evaluate the remaining potentially active faults, and to determine which of them "constitute a potential hazard" that warrants zoning. Except for the periodic updating of the earlier issued maps whenever new information is received, and taking advantage of opportunities to zone new breaks after earthquakes, the main thrust of the continuing program is to evaluate the host of less-known faults in California shown in red on Figure 1.

TEN-YEAR WORK PLAN, 1976-1986

This section of this report presents the Division of Mines and Geology's plan for a ten-year program to complete the evaluation and zoning of potentially hazardous faults in California.

Title of Program

This program will be known as the California Division of Mines and Geology Active Fault Mapping and Evaluation Program. It is a continuation, with modifications, of the Special Studies Zones mapping program mandated by the Alquist-Priolo Special Studies Zones Act of 1972.

Objective of Program

The objective of the Active Fault Mapping and Evaluation Program is to evaluate all potentially active faults in California, to estimate their individual degrees of potential for future surface rupture, and to delineate special studies zones along those faults with sufficient hazard or (highest potential). At the proposed level of funding and staffing, this program will be complete by 1986. After that, maintenance-level activities will continue, maintaining current information on California's active faults, keeping fault maps up to date and available to the public, maintaining an open file of geologic reports on sites within special studies zones, and providing requested information about the Act to the public agencies and individuals who request it--all under the Division's basic responsibility for public safety from geologic hazards.

Products of the Program

The principal output of the program will be a series of about 500 Special Studies Zones maps, on U.S. Geological Survey 1:24,000 topographic bases, or on orthophotomap bases when they become available. An estimated 25 new maps will be issued each year, plus about 10 updated and revised versions of previously issued maps of the series, depending on the availability of new data. The maps will show, as accurately as knowledge and available workforce permit:

1. All known surface traces of active (Holocene; 11,000 years) and associated potentially active (Quaternary; about last 2,000,000 years) faults.

2. Sources of information used preparing each map, and wherever feasible, notations of critical local data on each fault -- dates it was active, type of movement, recurrence, references, etc.

3. Carefully delineated Special Studies Zones, as narrow as practical, along those faults that warrant them.

Internal files to be kept throughout the program will indicate, for every potentially active fault evaluated under this program, the key evidence used for all decisions whether or not it warranted zoning.

Coproducts of the program will be fault evaluation information shared with other Division programs such as:

1. County environmental geology studies

2. Review reports for major public projects -- nuclear reactor sites, dams, tunnels, bridges, aqueducts, etc.

3. Statewide and regional maps such as the Fault Map of California, Fault Hazards in the Coastal Zone, etc.

The files will be accessible to other State, Federal, and local agencies for such purposes as public works planning, land-use planning (e.g. Safety element of general plans); pre-disaster planning, etc.

An administrative output of the program will be an annual summary of progress made, as a section of the Annual Report of the State Geologist.

Methods of the Program

The 10-year program starts on January 1, 1976, with the present state of knowledge of the State's hundreds of active and potentially active faults, best represented on the Division of Mines and Geology's forthcoming Fault Map of California, scale 1:750,000, Geologic Data Map 1, to be released early in 1976. Figure 1, page 5, shows in red color, at very reduced scale, the faults shown on that map known to have been active during Quaternary time, including Holocene and Historic time. All those red faults are potentially active until further investigation indicates otherwise; all will be mapped and evaluated, and those that warrant it will be zoned under this program. As additional updated information becomes available to the State Fault Map project, it will be used in this program, too.

Careful estimates indicate that about 4,500 linear miles of potentially active Quaternary and Historic faults are known in California, as shown in red on Figure 1. About 1,400 miles of that total have been mapped and zoned in the Special Studies Zones mapping program to date, leaving about 3,000 miles to be examined during the 10-year program, 1976-85 -- about 300 miles per year. Figure 5 shows the planned division of the statewide workload into 10 work areas based on approximately equal division of the 10-year workload. The dates within each planned work area indicate the planned priorities for completing the fault studies in that area. These priorities reflect two factors: 1) population expansion, and 2) known or suspected active faults.

In each work area, the evaluation phase will be conducted first, over a 12-month period, to identify and map those faults that are sufficiently active and well-defined to warrant zoning under the Act. This phase will include 1) an evaluation of available maps and reports, followed by 2) interpretation of available aerial photographs and of remotely sensed imagery. Field examination and limited mapping of critical sites, will be conducted to verify geologic and interpretive fault data, and to make independent observations. Interpretive activities and field observations will be omitted or reduced for those few faults on which complete and reliable data are already available. Operational criteria will be developed for evaluating the available fault rupture data, in order to estimate the future rupture potential of each fault. Estimates of recency of faulting and, if feasible, estimates of magnitude and sense of displacement will be used to help classify the faults in terms of their relative potential for surface rupture.

The planned work area schedule is not inflexible, especially with respect to targets of opportunity. Whenever new information on previously zoned faults becomes available, the previous map will be revised promptly. Also, whenever earthquakes occur, or other new information is received indicating significant hazard on any fault -- especially, in densely populated areas -- immediate attention will be shifted to evaluating and zoning the particular fault involved, no matter which work area it is in.

ACTIVE FAULT MAPPING AND EVALUATION PROGRAM
PLANNED WORK AREAS AND PRIORITIES

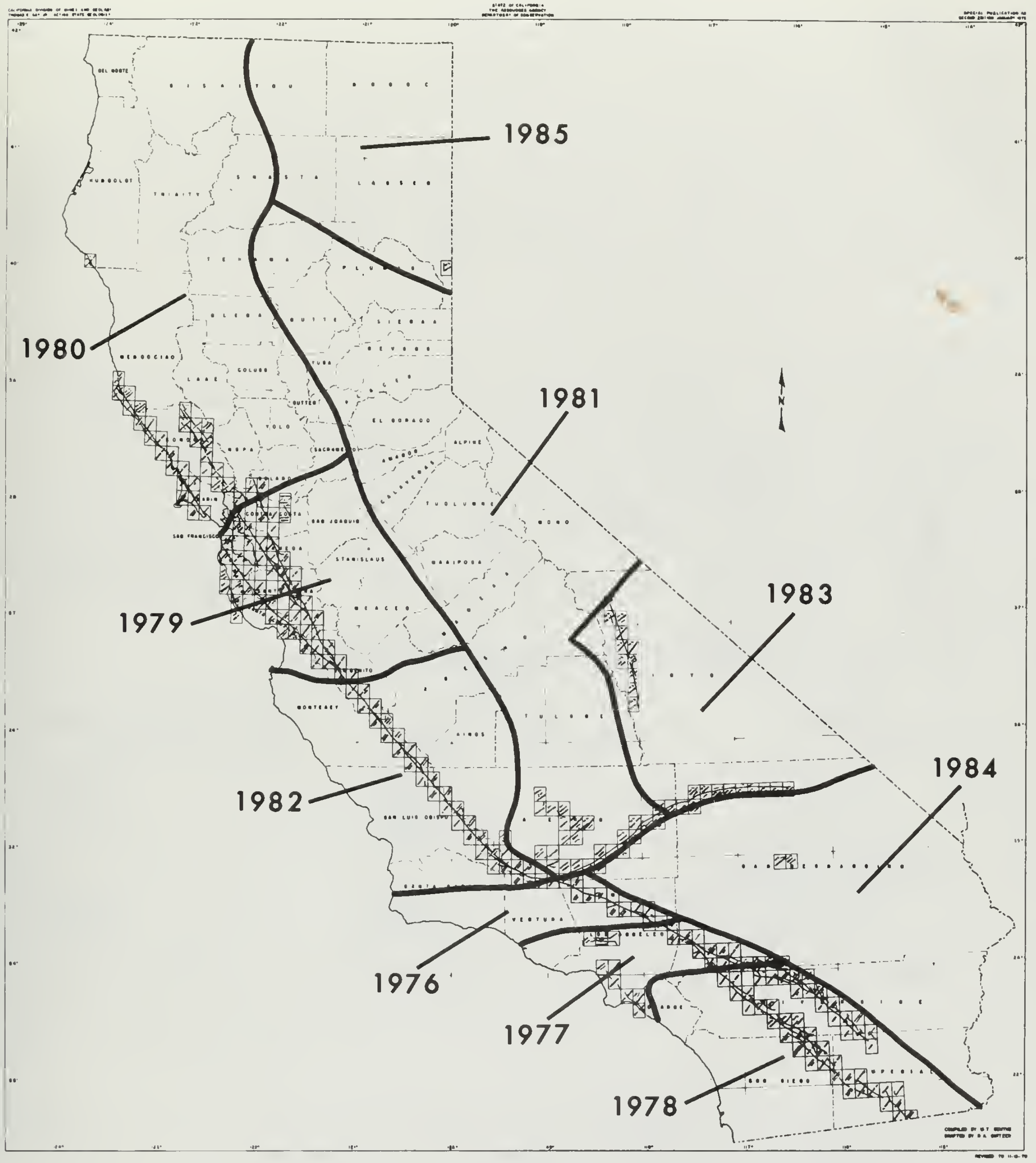


Figure 5. Map of California showing the Division of Mines and Geology's work plan and priorities for the Active Fault Mapping and Evaluation program, 1976-1985. All potentially active faults in each work area will be evaluated during the year indicated, and those faults determined to be active will be zoned with special studies zones.

Upon completion of the evaluation phase for each work area, a report and maps summarizing the findings will be evaluated by the State Geologist at the end of the year for decision regarding zoning. As appropriate, zones then will be delineated in accordance with Section 2622 of the Public Resources Code, during the first three months of the year following the evaluation phase. Following issuance of the preliminary maps about April 1 each year, the 90-day review period will end about July 1 each year. The 90-day revision period will end with the issuance of the Official Special Studies Zones Maps about October 1 each year, to end the 21-month cycle. Thus, the official maps of the 1976 work area will be released October 1, 1977, and those of the final year, 1985, will be released October 1, 1986.

Statement of Costs

The program is funded in the amount of $94,167[1/] in fiscal year 1975-76. This funding level provides for five positions and supporting operating expense, most of which is applied to the reproduction of preliminary and final versions of maps that are distributed to all affected agencies and local governments. A continuation of this funding level will be required for the ten year period 1976 through 1985, during which fault evaluation and zoning will be done. Starting in 1986, the maintenance program mandated in the Act will require continued funding in the amount of about $45,500 per year.

The following table provides fund expenditure detail:

Expense	1976-1985		1986 and following	
	man year	cost	man year	cost
Salaries				
Geologist	3	$ 59,100	1	$ 24,420
Drafting Technician	1	13,596	¼	3,399
Clerical	1	8,808	½	4,404
Staff benefits		16,300		6,445
Operating Expense				
Map reproduction		3,500		3,000
Field and support		9,000		3,800
Total annual program cost		$ 110,304[1/]		$ 45,468

[1/] The $16,137 difference between amount funded and actual cost of the Active Fault Mapping and Evaluation Program will be accommodated by diverting manpower part of the year, by lowered map-reproduction costs as fewer maps are zoned, and by charging inter-program activiity costs, with the sharing program (e.g. Fault Map of California, environmental geology program, etc.)

APPENDICES

Appendix A: Alquist-Priolo Special Studies Zones Act, verbatim including amendments prior to January 1, 1976.

Appendix B: Policies and Criteria of the State Mining and Geology Board, including revisions prior to January 1, 1976.

Appendix C: Guidelines for Evaluating the Hazard of Fault Rupture. (Issued as Division of Mines and Geology CDMG Note 49, October 1975.)

APPENDIX A

ALQUIST-PRIOLO SPECIAL STUDIES ZONES ACT

Excerpts from California Public Resources Code
(Signed into law December, 1972; amended September 26, 1974,
May 4, 1975 and September 28, 1975)

DIVISION 1. ADMINISTRATION

CHAPTER 2. DEPARTMENT OF CONSERVATION

Article 3. State Mining and Geology Board and the Division of Mines and Geology

660. There is in the department a State Mining and Geology Board consisting of nine members appointed by the Governor.

673. The board shall also serve as a policy and appeals board for the purposes of Chapter 7.5 (commencing with Section 2621) of Division 2.

DIVISION 2. GEOLOGY, MINES AND MINING

CHAPTER 7.5. SPECIAL STUDIES ZONES

2621. This chapter shall be known and may be cited as the Alquist-Priolo Special Studies Zones Act.

2621.5. It is the purpose of this chapter to provide for the adoption and administration of zoning laws, ordinances, rules, and regulations by cities and counties in implementation of the general plan that is in effect in any city or county. The Legislature declares that the provisions of this chapter are intended to provide policies and criteria to assist cities, counties, and state agencies in the exercise of their responsibility to provide for the public safety in hazardous fault zones.

This chapter is applicable to any project, as defined in Section 2621.6, upon issuance of the official special studies zones maps to affected local jurisdictions, but does not apply to any development or structure in existence prior to the effective date of the amendment of this section at the 1975–76 Regular Session of the Legislature.

2621.6. (a) As used in this chapter, "project" means

(1) Any new real estate development which contemplates the eventual construction of structures for human occupancy, subject to the Subdivision Map Act (commencing with Section 66410 of the Government Code).

(2) Any new real estate development for which a tentative tract map has not yet been approved.

(3) Any structure for human occupancy, other than a single-family wood frame dwelling not exceeding two stories.

(4) Any single-family wood frame dwelling which is built or located as part of a development of four or more such dwellings constructed by a single person, individual, partnership, corporation, or other organization. No geologic report shall be required with respect to such single-family wood frame dwelling if the dwelling is located within a new real estate development, as described in paragraph (1) or (2) of this subdivision, for which development a geologic report has been either approved or waived pursuant to Section 2623.

(b) For the purposes of this chapter, a mobilehome whose body width exceeds eight feet shall be considered to be a single-family wood frame dwelling not exceeding two stories.

2621.7. This chapter, except Section 2621.9, shall not apply to the conversion of an existing apartment complex into a condominium. This chapter shall apply to projects which are located within a delineated special studies zone.

2621.8. This chapter shall not apply to alterations or additions to any structure within a special studies zone the value of which does not exceed 50 percent of the value of the structure.

2621.9. A person who is acting as an agent for a seller of real property which is located within a delineated special studies zone, or the seller if he is acting without an agent, shall disclose to any prospective purchaser the fact that the property is located within a delineated special studies zone.

2622. In order to assist cities and counties in their planning, zoning, and building-regulation functions, the State Geologist shall delineate, by December 31, 1973, appropriately wide special studies zones to encompass all potentially and recently active traces of the San Andreas, Calaveras, Hayward, and San Jacinto Faults, and such other faults, or segments thereof, as he deems sufficiently active and well-defined as to constitute a potential hazard to structures from surface faulting or fault creep. Such special studies zones shall ordinarily be one-quarter mile or less in width, except in circumstances which may require the State Geologist to designate a wider zone.

Pursuant to this section, the State Geologist shall compile maps delineating the special studies zones and shall submit such maps to all affected cities, counties, and state agencies, not later than December 31, 1973, for review and comment. Concerned jurisdictions and agencies shall submit all such comments to the State Mining and Geology Board for review and consideration within 90 days. Within 90 days of such review, the State Geologist shall provide copies of the official maps to concerned state agencies and to each city or county having jurisdiction over lands lying within any such zone.

The State Geologist shall continually review new geologic and seismic data and shall revise the special studies zones or delineate additional special studies zones when warranted by new information. The State Geologist shall submit all revised maps and additional maps to all affected cities, counties, and state agencies for their review and comment. Concerned jurisdictions and agencies shall submit all such comments to the State Mining and Geology Board for review and consideration within 90 days. Within 90 days of such review, the State Geologist shall provide copies of the revised and additional official maps to concerned state agencies and to each city or county having jurisdiction over lands lying within any such zone.

2623. The approval of a project by a city or county shall be in accordance with policies and criteria established by the State Mining and Geology Board and the findings of the State Geologist. In the development of such policies and criteria, the State Mining and Geology Board shall seek the comment and advice of affected cities, counties, and state agencies. Cities and counties shall require, prior to the approval of a project, a geologic report defining and delineating any hazard of surface fault rupture. If the city or county finds that no undue hazard of this kind exists, the geologic report on such hazard may be waived, with approval of the State Geologist.

After a report has been approved or a waiver granted, subsequent geologic reports shall not be required, provided that new geologic data warranting further investigations is not recorded.

2624. Nothing in this chapter is intended to prevent cities and counties from establishing policies and criteria which are stricter than those established by this chapter or by the State Mining and Geology Board, nor from imposing and collecting fees in addition to those required under this chapter.

2625. (a) Each applicant for approval of a project may be charged a reasonable fee by the city or county having jurisdiction over the project.

(b) Such fees shall be set in an amount sufficient to meet, but not to exceed, the costs to the city or county of administering and complying with the provisions of this chapter.

(c) The geologic report required by Section 2623 shall be in sufficient detail to meet the criteria and policies established by the State Mining and Geology Board for individual parcels of land.

2630. In carrying out the provisions of this chapter, the State Geologist and the board shall be advised by the Geologic Hazards Technical Advisory Committee consisting of nine members nominated by the State Geologist and appointed by the board. Members of the committee shall be selected and appointed on the basis of their professional qualifications and training in seismology, structural geology, engineering geology, or related disciplines in science and engineering, and shall possess general knowledge of the problems relating to geologic seismic hazards and building safety. The members of the committee shall receive no compensation for their services, but shall be entitled to their actual and necessary expenses incurred in the performance of their duties.

APPENDIX B

Policies and Criteria of the State Mining and Geology Board

(with reference to the
Alquist-Priolo Special Studies Zones Act
Chapter 7.5. Division 2. Public Resources Code.
State of California)

(Adopted November 23. 1973; revised July 1. 1974. and June 26. 1975)

The legislature has declared in the ALQUIST-PRIOLO SPECIAL STUDIES ZONES ACT that the State Geologist and the State Mining and Geology Board are charged under the Act with the responsibility of assisting the Cities, Counties, and State agencies in the exercise of their responsibility to provide for the public safety in hazardous fault zones. As designated by the Act, the policies and criteria set forth hereinafter are limited to hazards resulting from surface faulting or fault creep. This limitation does not imply that other geologic hazards are not important and that such other hazards should not be considered in the total evaluation of land safety.

Implementation of the ALQUIST-PRIOLO SPECIAL STUDIES ZONES ACT by affected Cities and Counties fulfills only a portion of the requirement for these Counties and Cities to prepare seismic safety and safety elements of their general plans, pursuant to Section 65302 (F) and 65302.1 of the Government Code. The special studies zones, together with these policies and criteria, should be incorporated into the local seismic safety and safety elements of the general plan.

The State Geologist has compiled and is in the process of compiling maps delineating special studies zones pursuant to Section 2622 of the Public Resources Code. The special studies zones designated on the maps are based on fault data of varied quality. It is expected that the maps will be revised as more complete geological information becomes available. Also, additional special studies zones may be delineated in the future. The Board has certain responsibilities regarding review and consideration of those maps prior to the time that they are finally determined. Cities, Counties and State agencies have certain opportunities under the Act to comment on the preliminary maps provided by the State Geologist and these Policies and Criteria. Certain procedures are suggested herein with regard to those responsibilities and comments.

Please note that the Act is not retroactive (Section 2621.5 of the Public Resources Code). It applies to every proposed *new* real estate development or structure for human occupancy that constitutes a "project" as defined under Section 2621.6 of the Public Resources Code.

Review of Preliminary Maps

The State Mining and Geology Board suggests that each reviewing governmental agency take the following steps in reviewing the preliminary maps submitted for their consideration:

1. All property owners within the preliminary special studies zones mapped by the State Geologist should be notified by the Cities and Counties of the inclusion of their lands within said preliminary special studies zones by publication or other means designed to inform said property owners. Such notification shall not of necessity require notification by service or by mail. This notification will permit affected property owners to present geologic evidence they might have relative to the preliminary maps.
2. Cities and Counties are encouraged to examine the preliminary maps delineating special studies zones and to make recommendations, accompanied by supporting data and discussions, to the State Mining and Geology Board for modification of said zones in accordance with the statute and within the time period specified therein.
3. For purposes of the Act, the State Mining and Geology Board regards faults which have had surface displacement within Holocene time (about the last 11,000 years) as active and hence as constituting a potential hazard. Upon submission of satisfactory geologic evidence that a fault shown within a special studies zone has not had surface displacement within Holocene time, and thus is not deemed active, the Mining and Geology Board may recommend to the State Geologist that the boundaries of the special studies zone be appropriately modified.

The definition of active fault is intended to represent minimum criteria only for all structures. Cities and Counties may wish to impose more restrictive definitions requiring a longer time period of demonstrated absence of displacements for critical structures such as high-rise buildings, hospitals, and schools.

Specific Criteria

The following specific and detailed criteria shall apply within special studies zones and shall be included in any planning program, ordinance, rules and regulations adopted by Cities and Counties pursuant to said SPECIAL STUDIES ZONES ACT:

A. No structure for human occupancy, public or private, shall be permitted to be placed across the trace of an active fault. Furthermore, the area within fifty (50) feet of an active fault shall be assumed to be underlain by active branches of that fault unless and until proven otherwise by an appropriate geologic investigation and submission of a report by a geologist registered in the State of California. This 50-foot standard is intended to represent minimum criteria only for all structures. It is the opinion of the Board that certain essential or critical structures, such as high-rise buildings, hospitals, and schools should be subject to more restrictive criteria at the discretion of Cities and Counties.

B. Application for a development permit for any project (as defined in Section 2621.6) within a special studies zone shall be accompanied by a geologic report prepared by a geologist registered in the State of California, and directed to the problem of potential surface fault displacement through the project site, unless such report is waived pursuant to Section 2623.

C. One (1) copy of all such geologic reports shall be filed with the State Geologist by the public body having jurisdiction within thirty days following acceptance by the approving jurisdiction. The State Geologist shall place such reports on open file.

D. A geologist registered in the State of California, within or retained by each City or County, must evaluate the geologic reports required herein and advise the body having jurisdiction and authority.

E. Cities and Counties may establish policies and criteria which are more restrictive than those established herein. In particular, the Board believes that comprehensive geologic and engineering studies should be required for any "critical" or "essential" structure as previously defined whether or not it is located within a special studies zone.

F. In accordance with Section 2625 of the Public Resources Code, each applicant for approval of a project within a delineated special studies zone may be charged a reasonable fee by the City or County having jurisdiction over the project.

G. As used herein the following definitions apply:

1. A "project" includes any structure for human occupancy or new real estate development as defined under Section 2621.6 of the Public Resources Code.

2. A "structure for human occupancy" is one that is regularly, habitually or primarily occupied by humans; excluding therefrom freeways, roadways, bridges, railways, airport runways, and tunnels. The excluded transportation structures should be sited and designed with due consideration to the hazard of surface faulting. Mobile homes, whose body width exceed eight (8) feet, are considered as structures for human occupancy

3. A "new real estate development" is defined as any new development of real property which contemplates the eventual construction of "structures for human occupancy."

APPENDIX C

GUIDELINES FOR EVALUATING THE HAZARD OF SURFACE FAULT RUPTURE

These guidelines are to assist geologists who investigate faults relative to the hazard of primary surface rupture. Subsequent to the passage of the Alquist-Priolo Special Studies Zones Act (1972), it has become apparent that fault investigations conducted in California are frequently incomplete or otherwise inadequate for the purpose of evaluating the potential of surface fault rupture. It is further apparent that statewide standards for investigating faults do not exist.

The investigation of sites for the possible hazard of surface fault rupture is a deceptively difficult geologic task. Many active faults are complex, consisting of multiple breaks. Yet, the evidence for identifying active fault traces is generally subtle or obscure and the distinction between recently active and long-inactive faults may be difficult to make. Once a structure is sited astride an active fault, the resulting fault-rupture hazard cannot be mitigated unless the structure is relocated, whereas when a structure is placed on a landslide, the hazard from landsliding often can be mitigated. Further, it is impractical from an economic, engineering, and architectural point of view to design a structure to withstand serious damage under the stress of surface fault rupture. Thus, the evaluation of a site for the hazard of surface fault rupture is a difficult and delicate procedure.

Because of the complexity of evaluating surface and near surface faults and because of the infinite variety of site conditions, no single investigative method will be the best, or even useful, at all sites. Nonetheless, certain investigative methods are more helpful than others in locating faults and evaluating the recency of activity.

The evaluation of a given site with regard to the potential hazard of surface fault rupture is based extensively on the concepts of recency and recurrence of faulting along existing faults. In a general way, the more recent the faulting the greater the probability for future faulting (Ziony and others, 1973). Stated another way, faults of known historic activity during the last 200 years, as a class, have a greater probability for future activity than faults classified as Holocene age (last 11,000 years) and a much greater probability of future activity than faults classified as Quaternary age (last 2-3 million years). Moreover, future faulting generally is expected to recur along pre-existing faults (Bonilla, 1970, p. 68). No doubt there are and will be exceptions to this, because it is not possible to predict the precise surface location of a new fault where none existed before.

As a practical matter, fault investigations should be directed at the problem of locating existing faults and then attempting to evaluate the recency of their activity. It is pointed out that data are obtained both from the site and outside the site area. The most direct method of evaluating recency is to observe (e.g. in a trench or road cut) the youngest geologic unit faulted and the oldest unit that is not faulted. Recently active faults also may be identified by direct observation of young, fault-related topographic features in the field, on aerial photographs, or on remotely obtained images. Other indirect and more interpretive methods are identified in the outline below. Some of these methods are discussed in Taylor and Cluff (1973), Sherard and others (1974), Slemmons (1972), Bonilla (1970), and Wesson and others (1975), but no comprehensive manual on the subject of fault investigation and evaluation exists at this time. Other specific and general guidelines on fault investigations and evaluations are listed in the Selected References below.

The following annotated outline provides guidelines for a complete fault investigation that may be applied to any project site, large or small. Fault investigations may be conducted in conjunction with other geotechnical investigations (see CDMG Notes 37 and 44). Although not all investigative techniques need or can be employed in evaluating a given site, the outline provides a check-list for preparing complete and well-documented reports. Since most reports on fault investigations are filed with and reviewed by local or State government agencies, it is necessary that the reports be adequately documented and carefully written to facilitate that review. The importance of the review process is stressed here, because it is the reviewer who must evaluate the adequacy of reports, interpret or set standards where they are unclear, and advise the governing agency as to their acceptability.

The scope of the investigation is dependent not only on complexity and economics of a project, but also on the level of risk acceptable for the proposed structure or development (Joint Committee on Seismic Safety, 1974, p. 9). Obviously, a more detailed investigation should be made for hospitals, high-rise buildings, and other critical or sensitive structures than for low-density structures such as wood-frame dwellings that are comparatively safe. The conclusions drawn from any given set of data, however, must be consistent and unbiased. Recommendations must be clearly separated from conclusions, since recommendations are not totally dependent on geologic factors. The final decision as to whether, or how, a given project should be developed lies in the hands of the owner and the governing body that must review and approve the project.

Suggested Outline for Geologic Reports on Faults

The following subjects should be addressed, or at least considered, in any geologic report on faults. Some of the investigative methods listed below should be carried out well beyond the site being investigated. However, it is not expected that all of the methods identified would be used in a single investigation.

I. Text

A. Purpose and scope of investigation

B. Geologic setting

C. Site description and conditions. Include information on geologic units, graded and filled areas, vegetation, existing structures, etc., that may affect the choice of investigative methods and the interpretation of data.

D. Methods of investigation

1. Review of published and unpublished literature and records concerning geologic units, faults, ground-water barriers. etc.

2. Interpretation of aerial photographs and other remotely sensed images to detect fault-related topography, vegetation and soil contrasts, and other lineaments of possible fault origin.

3. Surface observations, including mapping of geologic units and structures, topographic features, springs, deformation of man-made structures, etc., both on and beyond the site.

4. Subsurface investigations

a. Trenching and other extensive excavations to permit detailed and direct observation of continuously exposed geologic units and features which must be carefully logged (see Taylor and Cluff, 1973).

b. Borings and test pits to permit collection of data on geologic units and ground water at specific locations. Data points must be sufficient in number and adequately spaced to permit valid correlations and interpretations.

5. Geophysical investigations. These are indirect methods that require a knowledge of specific geologic conditions for reliable interpretations. They should seldom, if ever, be employed alone without knowledge of the geology. Geophysical methods alone never prove the absence of a fault nor do they identify the recency of activity. The types of equipment and techniques used should be described.

a. Seismic refraction

b. Magnetic intensity

c. Other (e.g. electrical resistivity)

6. Other methods should be included when special conditions permit, or requirements for critical structures demand, a more intensive investigation.

a. Aerial reconnaissance overflights.

b. Geodetic and strain measurements, microseismicity monitoring, or other monitoring techniques.

c. Radiometric analysis (e.g. C^{14}, K-Ar), stratigraphic correlation (fossils, mineralogy), soil profile development, paleomagnetism (magnetostratigraphy), or other age-dating techniques to identify the age of faulted or unfaulted units or surfaces.

E. Conclusions

1. Location and existence (or absence) of hazardous faults on or adjacent to the site.

2. Type of faults and nature of anticipated offset: direction of relative displacement, and maximum displacement that is possible.

3. Probability of or relative potential for future surface displacement. The likelihood of future ground rupture can seldom be stated mathematically, but may be stated in semiquantitative terms such as low, moderate, or high.

4. Degree of confidence in and limitations of data and conclusions.

F. Recommendations

1. Set-back distances from hazardous faults, if appropriate. State and local law may dictate minimum standards (e.g. see Hart, 1975).

2. Need for additional studies.

3. Risk evaluations relative to the proposed development--opinions are acceptable. But remember that the ultimate decision as to whether the risk is acceptable lies with the governing body.

II. References

A. Literature and records cited and reviewed.

B. Aerial photographs or images interpreted--list type, scale, source, index numbers, etc.

C. Other sources of information including well records, personal communications, and other data sources.

III. Illustrations--these are essential to the understanding of the report and to reduce the length of text.

A. Location map--identify site locality, significant faults, geographic features, seismic epicenters, and other pertinent data; 1:24,000 scale is recommended.

B. Site development map--show site boundaries, existing and proposed structures, graded areas, streets, exploratory trenches, borings, geophysical traverses, and other data; recommended scale is 1 inch equals 200 feet, or larger.

C. Geologic map--shows distribution of geologic units (if more than one), faults and other structures, geomorphic features, aerial photo lineaments, and springs; on topographic map 1:24,000 scale or larger; can be combined with III (A) or III (B).

D. Geologic cross-sections, if needed to provide 3-dimensional picture.

E. Logs of exploratory trenches and borings--show details of observed features and conditions; should not be generalized or diagrammatic.

F. Geophysical data and geologic interpretations.

IV. Appendix--supporting data not included above (e.g. water well data).

V. Signature and registration number of investigating geologist.

Selected References

Association of Engineering Geologists, 1973, Geology and earthquake hazards -- Planners guide to the seismic safety element: AEG, Southern California Section, 44 p. (See Section II on Evaluating the Problem.)

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